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A Survey of Winter Damage in the Forests of Montana, 1989

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USDA Forest Service
Northern Region



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by

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INTRODUCTION

During the winter of 1988-89, a series of meteorological phenomena occurred in parts of the Northern Rockies and caused extensive damage to many of the coniferous forests. Significant tree damage occurred in parts of western Montana, especially east of the Continental Divide, on the Helena, Deerlodge, and Lewis and Clark National Forests, with lesser and more widely scattered damage occurring elsewhere.

A classical explanation of winter injury in conifers is, briefly, excessive water loss in winter by the foliage (transpiration) which cannot be replaced because of frozen roots, stem, or soil. The transpiration is caused by unseasonal warming, sometimes intensified by wind. This foliage desiccation phenomenon has also been referred to as winter killing, winter drying, red belt and parch blight, depending on the circumstances and location (Boyce 1961). Red belt, the term most commonly used, refers generally to damage symptoms occurring along relatively well defined elevational zones, i.e., contours.

CAUSE

The exact cause of winter injury is not completely understood but there appears to be a strong relationship between foliage injury and relatively abrupt changes in air temperatures during winter. Most winter injury is thought to be induced by unseasonably warm air temperatures accompanied by drying winds or chinooks (Henson 1952, Boyce 1961) or by similar warming trends followed by intensive cold (Robins and Susut 1974). The latter sequence appeared to be the case in Montana during 1989, specifically during an 8-day period during late January and early February, when the Region was suddenly enveloped by a continual arctic air mass. Records from five weather stations¹ in Montana during 1989 showed generally above average temperatures occurring in January with even higher temperatures recorded during the 3-day period, 28-30. This was followed by sudden and drastic drops in air temperature during January 31 and the first 3-4 days of February, temperatures at all weather stations falling and remaining below -20°F. On January 31, the temperature in Great Falls dropped from a high of 51°F to a low of -23°F, a difference of 74° in less than 24 hours. In Helena, a drop of 70° was recorded. At 0800 hours on February 3, Missoula recorded a windchill factor of -77°F. Following this sudden cold spell, air temperatures gradually increased beginning the second week in February, and with some variation, returned to normal. Sustained, subzero temperatures during early February in Montana are not abnormal, but the sudden and drastic change from unseasonably warm to unseasonably cold in such a short period of time is considered a "near" record.²

¹ Monthly climatological data from national weather service offices, Billings, Great Falls, Havre, Helena, and Missoula, MT.

² Personal communication with Lloyd Heavner, Meteorologist in Charge, National Weather Service, Missoula, MT.

THE PROBLEM

With advance of spring, the normally green crowns of lodgepole pine turned yellow, then orange, and by early summer, a deep reddish-brown. East of the Continental Divide, in the most badly damaged areas, entire hillsides took on a scorched appearance, resembling the aftermath of a forest fire (Figure 1). The heaviest injury was to lodgepole pine but ponderosa pine, Douglas-fir, Engelmann spruce, western white pine, subalpine fir, western larch and whitebark pine were also affected. In many of the valleys, fruit orchards were badly damaged, and many ornamental trees and shrubs were killed in communities.



Figure 1.--A "pocket" of winter-damaged lodgepole pine.

In early July, once damage symptoms became obvious, National Forest Zone personnel in Helena conducted an aerial survey to locate and map those stands estimated to be the most seriously damaged. Later during the summer, the damage was mapped Regionwide by Forest Pest Management aerial sketchmap specialists (Table 1).

Table 1.--Acres of winter injury in Montana during 1989 by intensity class as determined by aerial survey.

Area	Light	Moderate ¹	Heavy	Total
Beaverhead NF ²	219	4,253	354	4,826
Bitterroot NF	--	1,324	--	1,324
Custer NF	--	9,541	--	9,541
Deerlodge NF	1,729	6,167	4,562	12,458
Flathead NF	68	32,936	--	33,004
Gallatin NF	1,085	12,527	135	13,747
Helena NF	89,383	97,579	92,317	279,279
Lewis & Clark NF	39,047	51,437	9,461	99,945
Lolo NF	828	15,950	8,866	25,644
Totals	132,359	231,714	115,695	479,768

¹ In those Forests where winter damage was mapped without regard to intensity, the acreage was entered in the moderate column.

² Includes lands of all ownerships on the National Forest map.

Due to the apparent seriousness of the problem and its suspected effect on resource use and values, it was decided to conduct an evaluation survey to determine the nature of injury in the most heavily damaged areas and to initiate a method whereby longer term effects of the damage on individual trees could be determined and documented.

METHODS

Following the initial aerial survey, Regional pest management personnel met with Helena National Forest Zone and District personnel for a briefing on the problem and to identify priority areas and develop general survey procedures. Briefly, a subjective method for visually estimating the degree of foliar damage to individual trees was developed using a numerical rating system. The presence or absence of new growth was also observed with the aid of binoculars and both estimates were recorded on a prepared form (Appendix A).

Three survey procedures were used; all required optimum light conditions.

Stand damage assessment surveys provided ready estimates of the degree and extent of winter injury to the stand. Once the damaged stand was located, a transect or series of transects was established and at predetermined intervals, usually 2 or more chains, five trees (greater than 7 inches d.b.h.) were randomly selected for examination. The crown of each tree was classified into one of four damage classes (Appendix A) and judged as to contain new growth or not. Following each survey, the ratings were totaled and an overall damage rating computed.

Stand reexamination procedures entailed permanent marking of 25 trees in a stand for reexamination at later dates to assess their condition over time. These trees were subjectively selected to portray a range of crown

conditions--from mostly green to apparently dead, although in some areas neither category could be fulfilled. Each tree crown was observed and rated as stated above. Azimuths were recorded between trees to facilitate relocation.

Photo plots were established to provide a comparative, visual record of current tree damage with whatever changes may occur in the future. The scenes ranged from individual trees, to groups of trees in reproduction areas, to entire stands. The center of each photo plot was marked with a wooden stake for reference and rephotography. Relevant data were recorded at each plot including direction (azimuth), light conditions, focal length, date and time of day, as well as a short description of the scene. In some cases, it was possible to take two or more scenes from the same point.

FINDINGS AND OBSERVATIONS

The first reexamination plot was established July 26 in a lodgepole pine stand (elevation 6,400 feet) (Appendix B). Of the 25 trees tagged and classified as to foliar damage, 22 were judged as having no new growth. When new needle growth was observed, it was stunted and contorted, and occurred on only a few terminals, almost always in the upper crown. It was assumed at this late date that shoot growth had ceased, or nearly so, since shoot elongation has normally stopped by late July (Oreily and Owens 1985) or early August (Horton 1958). As the summer progressed and more lodgepole pine stands were examined, more shoot elongation was observed, even in the more heavily damaged trees. It was suspected that for reasons not understood, initial shoot growth had been set back by bud damage inflicted by the extreme winter temperatures and that growth had continued through August, possibly into September. The plots were reexamined during the first half of September (Table 2).

Table 2.--Changes in shoot growth in five reexamination plots during two examination periods (25 trees per plot).

		New Growth Recorded				
		Examination Period				
Plot No. ¹	Tree spp.	1	2	1	2	Change
		- - -Date- - -		- - - Number of Trees- - -		
1	LP	7/16	9/1	3	22	+ 19
2	LP	7/28	9/11	8	20	+ 12
3	DF	8/4	9/11	4	6	+ 2
4	S	8/9	9/12	18	23	+ 5
5 ²	LP	8/17	9/12	15	15	0

¹ The trees in plots 1-4 were also in stands 1-4, respectively, listed in Appendix B. However, they were different trees.

² In this plot three trees exhibited shoot growth since the initial examination (8/17), but the new growth recorded in these trees during the first examination appeared to have died in the interim. Those trees appeared to be dead.

Practically all forested areas, all coniferous species, and all age classes in Montana were affected to some degree by this winter injury syndrome. Mature and over-mature lodgepole pine stands east of the Continental Divide experienced by far the most extensive and serious damage.

The occurrence and distribution of the winter injury in Montana as mapped during the routine forest pest aerial reconnaissance is shown in Figure 2.

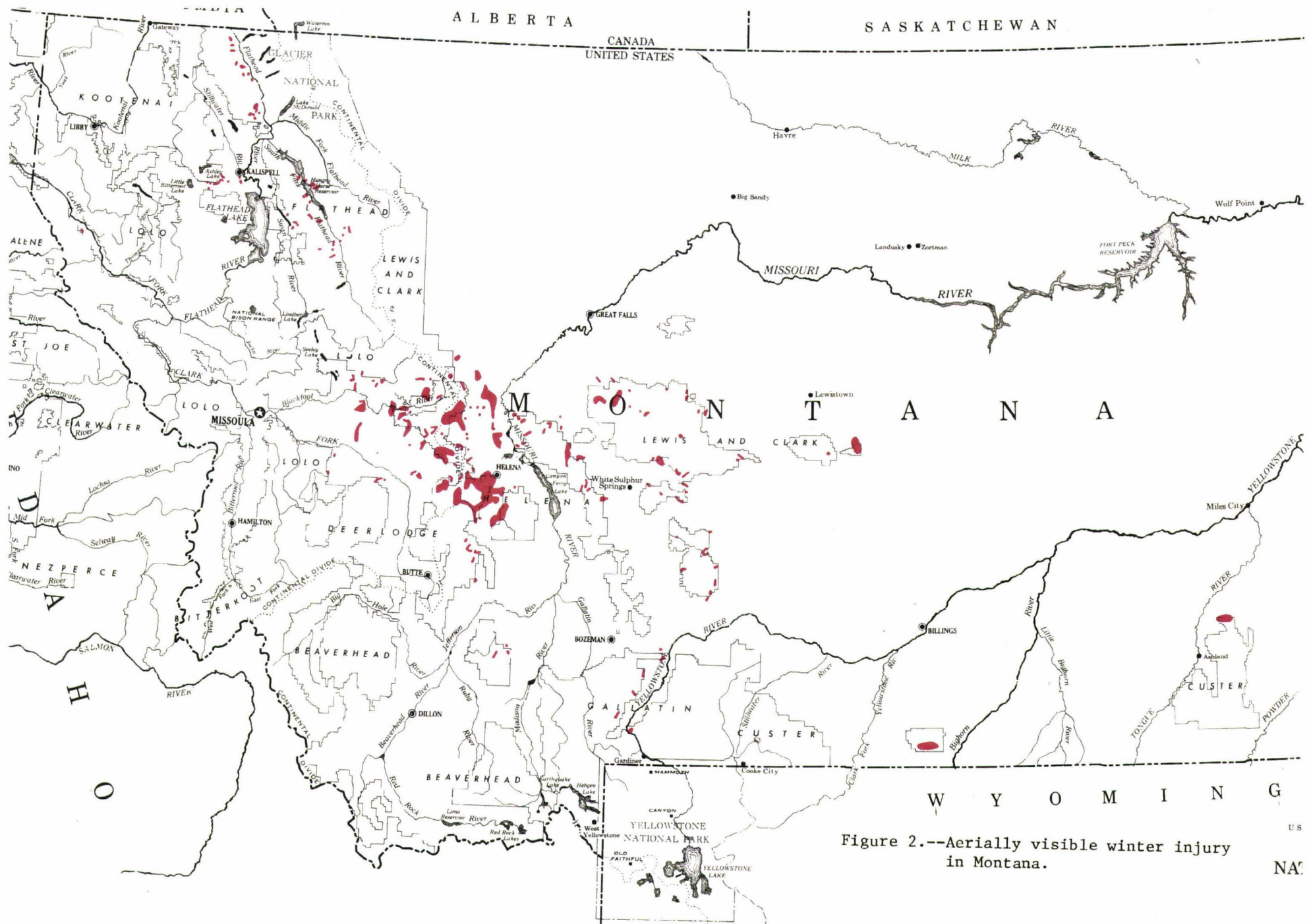


Figure 2.--Aerially visible winter injury in Montana.

Stand damage assessment surveys were conducted in six stands, four on the Helena National Forest and two on the Deerlodge National Forest (Appendix B.)

In reporting winter injury of lodgepole pine in Alberta, Canada, Henson (1952) mentioned that only the preceding year's growth was affected. In this occurrence, however, all living foliage was affected regardless of tree species. The pines and subalpine fir retained most of their injured needles through summer and fall. Douglas-fir lost only parts of their crowns, while spruce were totally defoliated. In some areas, the remaining green needles of Douglas-fir turned shades of yellow during late summer and fall. The new growth of larch in badly injured, mixed stands was extremely bushy and stunted, apparently due to a proliferation of late, adventitious budding. Staminate and ovulate buds of western larch in Montana were almost totally destroyed.³

In mature and over-mature stands, exposed trees next to openings, natural or humanmade, exhibited the heaviest foliage injury (Figure 3). Within the stands, crowns were more protected and showed less damage.



Figure 3.--Heavy winter injury surrounding stand openings.

Reproduction areas also exhibited heavy damage, especially east of the Continental Divide. As in mature stands, all species were affected, particularly lodgepole pine since it is so abundant. In direct contrast to the badly injured, mature stands, most reproduction showed considerable new growth, including the terminal leader even though all of the previous growth had been killed (Figure 4). The lower parts of the crown covered by snow were uninjured. Although no definitive data was taken in reproduction areas, other than the establishment of several photo plots, it is felt that those trees containing considerable new growth will survive.

³ Personal communication with Clint Carlson, Intermountain Forest and Range Experiment Station, Missoula, MT.



Figure 4.--Damaged lodgepole pine saplings (note new growth)

During the stand damage assessment surveys, all trees were injured to some degree (Table 3). Of the 600 trees observed, 33 percent lost 50 percent of their crowns or more, and roughly 17 percent lost more than 75 percent of their crown. Most of last year's buds had been killed and new growth, when it was present, was negligible. It is highly unlikely that many of the most seriously injured trees will survive and for those that do, it will be several years before they recover sufficiently to accumulate increment. It is also felt that the presence of new growth in many of the badly injured trees is a symptom of stress rather than survival. Much of this succulent, delayed growth may not harden before the fall frosts. Some of the trees have already succumbed, some will certainly die in 1990 while others may take longer. Some indication of this survival/mortality trend will become evident by annual monitoring of the trees in the reexamination and photo plots.

Table 3.--Summary of crown injury and new growth estimates made during stand damage assessment surveys in Montana (100 trees per stand), 1989.

Stand No. ¹	Tree species ²						Crown injury class ³				New growth	Date examined
	LP	DF	AF	S	WB	L	(1)	(2)	(3)	(4)		
	----- Number of Trees -----											
1	100	--	--	--	--	--	42	22	22	14	57	7/25
2	96	--	3	1	--	--	62	18	14	6	72	7/28
3	56	44	--	--	--	--	38	23	18	21	18	8/4
4	29	1	32	37	--	1	49	24	5	22	71	8/9-8/10
5	100	--	--	--	--	--	37	31	17	15	88	8/22
6	94	--	--	--	6	--	13	43	22	22	86	8/30

¹ See Appendix B for stand information.

² LP = Lodgepole pine; DF = Douglas-fir; AF = Subalpine fir; S = Engelmann spruce; WB = whitebark pine; L = western larch.

³ Percent crown containing dead foliage: (1), <25; (2) 26-50; (3) 51-75; (4) >76.

It was apparent that shoot elongation in the damaged mature and over-mature stands was significantly delayed, well beyond its normal growth period. In all of the five plots reexamined, shoot growth continued between the two examination periods. Observations made in adjacent non-damaged stands and reproduction areas did not reveal this abnormality; if it did occur, it certainly wasn't as pronounced or obvious.

Above average temperatures in late January followed by a sudden and drastic temperature drop is thought to be the principal cause of this extensive injury, although the physiological processes of the injury are not well understood. The intensity of damage is also believed to have been increased by past weather patterns, since the preceding years, 1986 through 1988, were drought years. By the time the trees approached the winter of 1988-89, they were already under stress, had already utilized much of their reserves, and were ill-prepared for extreme winter temperatures. Fortunately, normal to above normal precipitation occurred during the 1989 growing season, which, hopefully, will boost any recovery tendencies.

The long-term consequences of this winter injury will not be known for some time. Presently, the visual impact of this damage as seen close up and from afar, is somewhat alarming. In past occurrences in Alberta, Canada, considerable mortality in lodgepole stands was reported to have occurred (Robins and Susut 1974).

Many of the badly weakened trees that manage to survive through 1990 may eventually succumb to other factors, such as bark beetles, disease, or unfavorable weather conditions. Although the appearance of winter injury is often spectacular in the Pacific Northwest, it is short lived and seldom, if ever, causes insect outbreaks (Furniss and Carolin 1977).

In those badly injured lodgepole stands, bark beetles should not pose a serious problem. Secondary insects such as *Ips* spp., red turpentine beetles, the Sequoia pitch moth, and twig beetles have already attacked some severely injured trees. Some mountain pine beetle attacks may occur but it is highly unlikely that their progeny will survive. Attacks by root diseases such as *Armillaria* sp. could occur.

The affected Douglas-fir may attract and nurture Douglas-fir beetle populations that will emerge and attack green trees in 1990 but will not show up as "faders" until 1991. Damaged large-diameter Engelmann spruce may attract the spruce beetle, but the affected trees are so few and widely scattered that they do not represent a serious problem. Some of the weakened subalpine firs will probably be attacked by secondary bark beetles which will not pose a threat to nearby trees. All species will be susceptible to root diseases.

DISCUSSION

Western spruce budworm populations infesting stands affected by winter injury have been significantly reduced. Hibernating larvae can withstand very low temperatures but following the needle-mining stage in the spring, they starved due to lack of new foliage to feed upon.

To label this damage as "red belt" would be a misnomer. The classical red belt injury is visible along relatively well defined horizontal strata which did not ordinarily occur in this situation. Most injury in the extensive lodgepole stands directly east of the Continental Divide appeared to occur in patches or pockets without respect to elevation, aspect, or topographic position.

In order to determine the impact of this winter injury on those stands examined and the fate of the individual trees tagged and photographed, follow-up surveys will be conducted in 1990 and possibly even later since some trees may take several years to die. It is thought, however, that whatever mortality will occur, most will be evident in 1990. The visual impressions of foliar change, favorable or unfavorable, as determined by a series of color slides, should prove to be a valuable supplement to those findings. The findings of the reexamination survey will be reported in 1991.

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APPENDIX A

Example of field form used for recording damage and new growth estimates during stand damage assessment and reexamination surveys.

Winter Injury Tree Rating System						
Area: _____			Survey Type ¹ _____			
Date: _____			Survey Method ² _____			
Spp: _____			Weather: _____			
Elev: _____			Aspect: _____			
			Observer: _____			
Tree			Foliage ³			Remarks
No.	Sp.	DBH	Live	Dead	New ⁴ growth	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

¹ Stand damage assessment or reexamination

² Transect, random, non-random, etc.

³ Percent crown with dead foliage:

(1) = <25; (2) = 26-50; (3) 51-75; (4) = >76

⁴ New growth, Yes (Y) or No (N).

APPENDIX B

Location and other data pertinent to stand damage assessment and reexamination plots.

			Survey type ¹					
No.	Forest	Area	A	R	Tree sp. ²	Elev. (ft.)	Aspect	Geographic description
1	Helena	Bryan Cr.	X	X	LP	6400	S	T.8N., R.6W., S½ Sec. 3
2	Helena	Bullion Park	X	X	LP	6700	SW	T.8N., R.6W., S½ Sec.2
3	Helena	Cave Gulch	X	X	DF	6420	NW	T.11N., R.7W., S½ Sec. 6
4	Helena	Copper Cr.	X	X	S	5540	NNW	T.15N., R.9W., S½ Sec. 2
5	Deerlodge	Pocurpine Cr.	X	X	LP	6400	NE	T.5N., R.5W., N½ Sec. 3
6	Deerlodge	Cataract Cr.	X			7400	NW	T.7N., R.5W., N½ Sec. 3
7	Helena	Granite B.		X	LP	6900	W	T.13N., R.7W., SW¼ Sec. 27
8	Flathead	Betty C.		X	WP	3800	SW	T.28N., R.7W., NE¼ Sec. 28

¹ A = Stand damage assessment; R = Reexamination

² Tree species - Reexamination plots only. See Table 2 for tree species examined during assessment surveys.